

AI-Powered USB Handbook

USB

AI-Powered USB Handbook Team

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1. AI-Powered USB Handbook

AI-Powered USB Handbook			
AI-Powered USB Handbook Type-C	USB	USB 3.2 Gen 2x2	Thunderbolt 4 (4)

1.1

- -
- USB - USB
- USB -
- Thunderbolt -
- - USB PD
- -

1.2

- 
- 
- 
- 

2. 1 (Introduction)

2.1

USB (Universal Serial Bus) Type-C			USB	USB 3.2 Gen 2x2
AI-Powered USB Handbook	USB	AI		

2.2

-
- 4 USB4
- USB

2.3

-
- USB 1.0 USB4
- Intel Thunderbolt USB
- USB PD PPS
-

3. 2 USB (USB Connector Types)

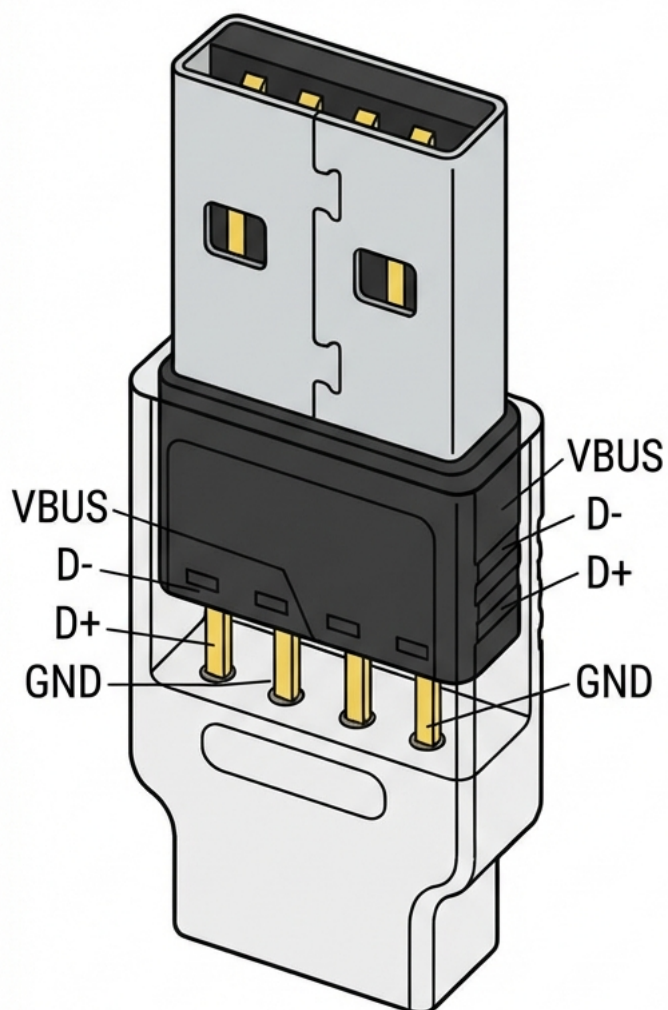
USB

3.1 USB Type-A

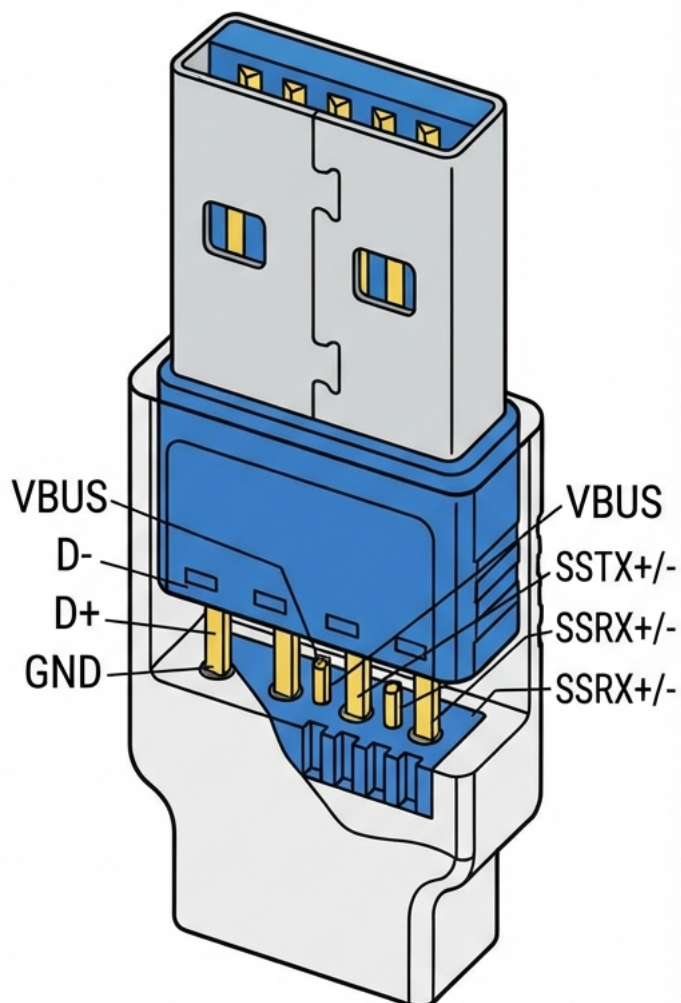
USB

-
-
- **USB 2.0** 4
- **USB 3.0+** 5 9

USB 2.0 Type-A



USB 2.0 Type-A

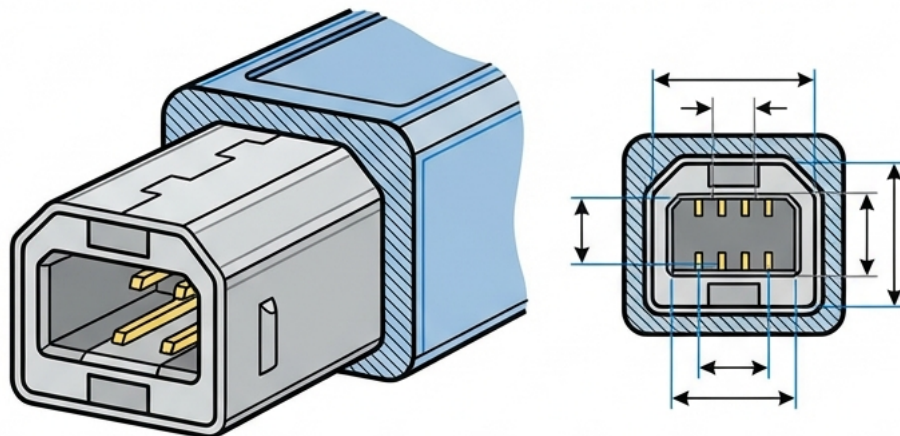
USB 3.0 Type-A
(SuperSpeed)USB 3.0 Type-A
(SuperSpeed)

3.2 USB Type-B

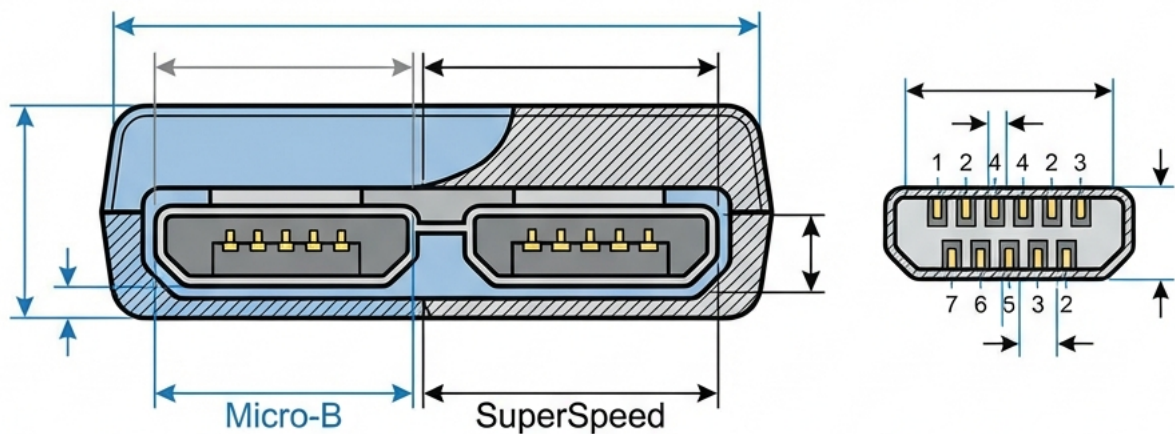
- Standard-B
- Micro-B (USB 3.0)

Elements

USB 3.0



USB Standard-B
(Printer)

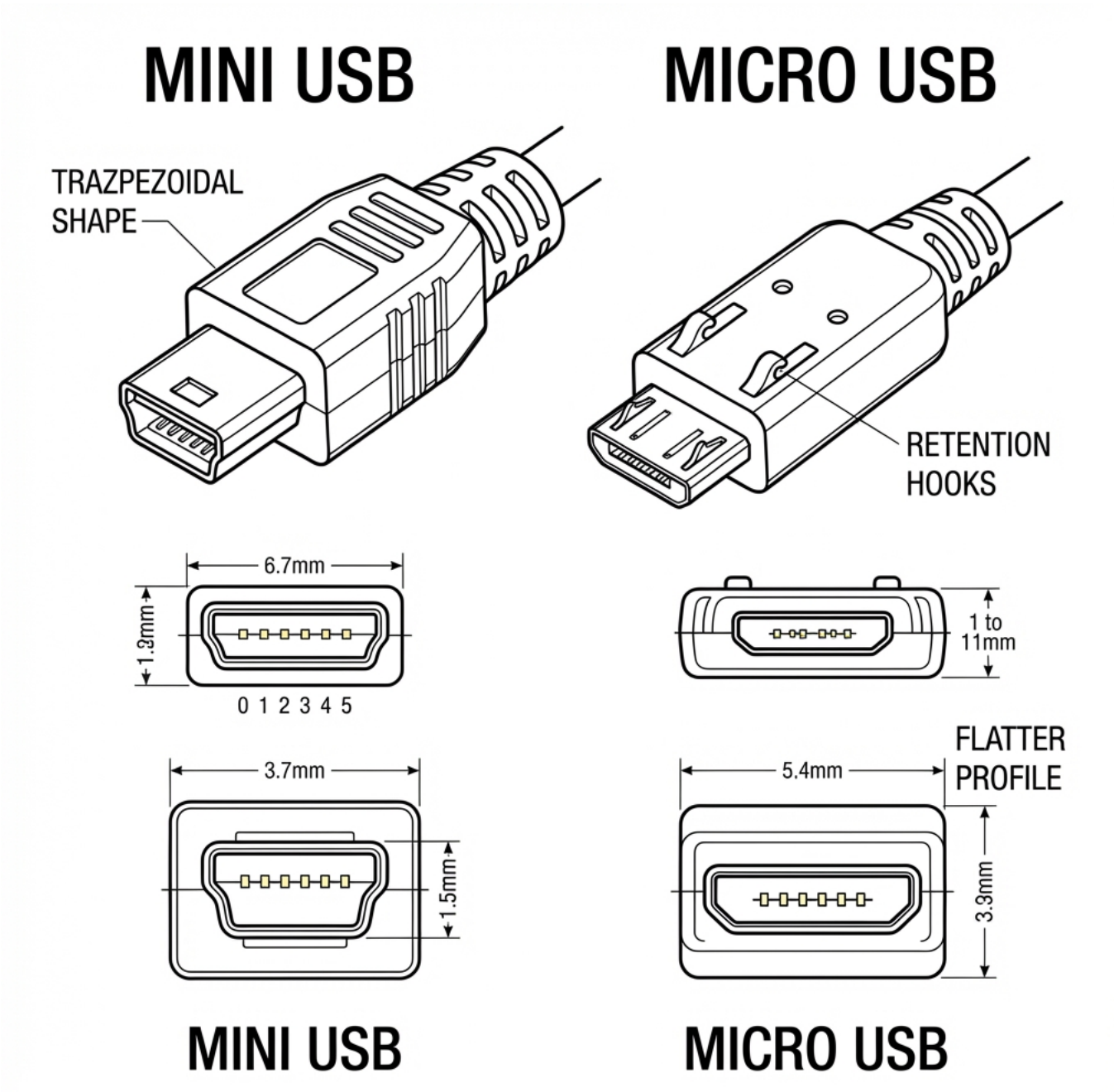


USB Micro-B SuperSpeed
(External HDD)

3.3 Mini USB & Micro USB

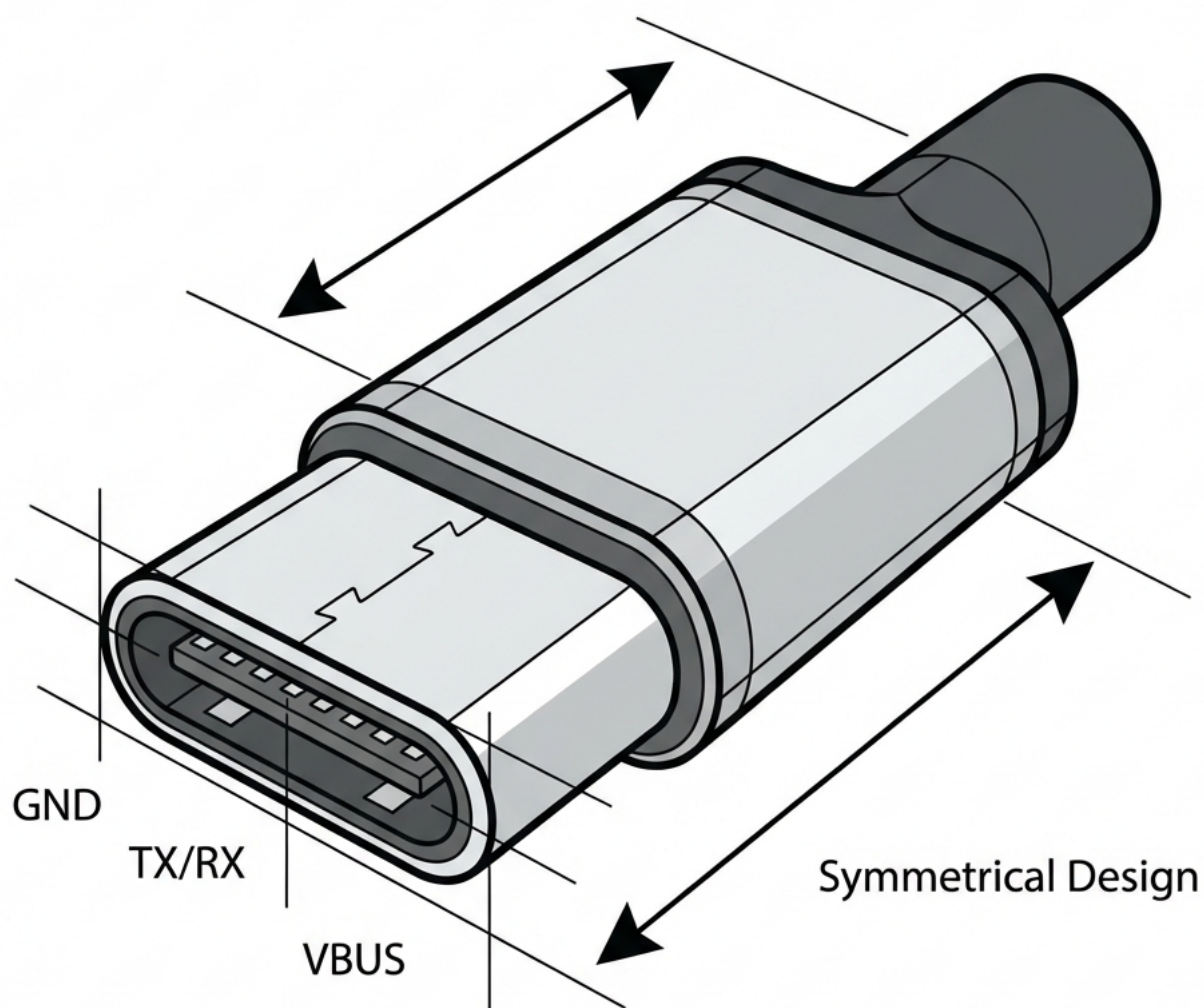
- **Mini USB** MP3
- **Micro USB**

USB 2.0



3.4 USB Type-C

•				
•				
•		DP Alt Mode	240W	USB PD
•	24	22	CC (Configuration Channel)	
•	Type-C	Type-C	USB 2.0	4



4. 3 USB (USB Transfer Protocols)

USB USB-IF (USB)

4.1

- **USB 1.0 / 1.1:**
- **Low Speed:** 1.5 Mbps ()
- **Full Speed:** 12 Mbps
- **USB 2.0:**
- **High Speed:** 480 Mbps “ ”

4.2 USB 3.x

	(2013)	(2019)			
USB 3.0	USB 3.1 Gen 1	USB 3.2 Gen 1	USB 3.0 / 5Gbps	5 Gbps	8b/10b
N/A	USB 3.1 Gen 2	USB 3.2 Gen 2	USB 3.1 / 10Gbps	10 Gbps	128b/132b
N/A	N/A	USB 3.2 Gen 2x2	USB 3.2 / 20Gbps	20 Gbps	128b/132b

USB 3.2 Gen 2x2 Type-C Type-C

4.3 USB4

USB4 Intel Thunderbolt 3

- **USB4 Gen 2x2:** 20 Gbps
- **USB4 Gen 3x2:** 40 Gbps ()
-
- **(Tunneling)** (USB 3.2) (DisplayPort) PCIe
- USB 3.2 USB 2.0 Thunderbolt 3

5. 4 Thunderbolt () (Thunderbolt Technology)

Thunderbolt Intel Apple “ ” “ ”

5.1 Thunderbolt 3 (3)

- USB Type-C
- 40 Gbps
- PCIe x4 () DisplayPort (5K/8K) USB
- 3 USB 3.x USB

5.2 Thunderbolt 4 (4)

4 40 Gbps

5.2.1 4 vs 3

- | | | | | | | |
|----------------|---|----------------|--------------------|----------|---------------|-----|
| 1. PCIe | 4 | PCIe | 32 Gbps (3 | 16 Gbps) | (eGPU) | SSD |
| 2. | 4 | 4K | 8K | (3 | 4K) | |
| 3. | | Intel VT-d DMA | DMA | | | |
| 4. | 4 | (Hub) | 1 3 | 3 | (Daisy Chain) | |

5.3 Thunderbolt vs USB4

- USB4 3
-
- **USB4** “ ” 20Gbps 40Gbps PCIe
- **Thunderbolt 4** “ ” 40Gbps PCIe Intel
- **Thunderbolt 4** **USB4** “ ”

6. 5

(Charging & Power Delivery)

USB

2.5W (5V 0.5A)

240W

6.1

6.1.1 USB BC 1.2 (Battery Charging)

USB BC 1.2

USB-IF

2010

- 7.5W (5V 1.5A)
- D+/D-
-
- **SDP (Standard Downstream Port)** USB 500mA
- **CDP (Charging Downstream Port)** + 1.5A
- **DCP (Dedicated Charging Port)** 1.5A
-

6.2

6.2.1

- 2010
- **USB 2.0** USB **2.5W** (5V 0.5A) 4-6
 - **USB BC 1.2** 7.5W (5V 1.5A)
 - USB PD 1.0 2012 2016 PD 3.0
 -
 - " 5 2 "
 -
 - 2013-2016 USB PD
- OPPO " "

[!IMPORTANT]

6.2.2

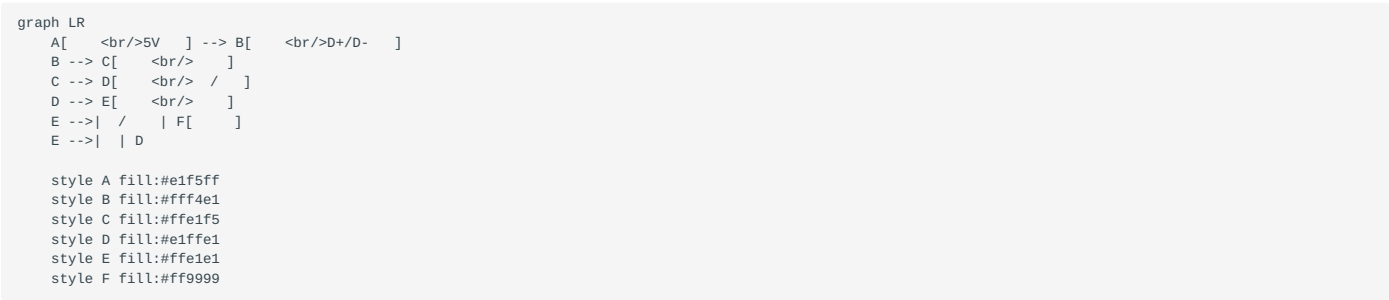
```

timeline
    title
    2010 : USB BC 1.2 (7.5W) :
    2012 : USB PD 1.0 : PD <br>
    2013 : QC 1.0 (10W) :
    2014 : QC 2.0 (18W) :
        : OPPO VOOC (20W) :
    2015 : FCP (18W) :
        : PE+ : MTK
    2016 : QC 3.0 : 200mV
        : SCP (22.5W) : <br>
        : USB PD 3.0 :
        : vivo (22.5W)
    2017 : PE 3.0 (30W)
        : QC 4 : USB PD
    2018 : OPPO SuperVOOC (50W) :
        : (27W)
        : QC 4+
```

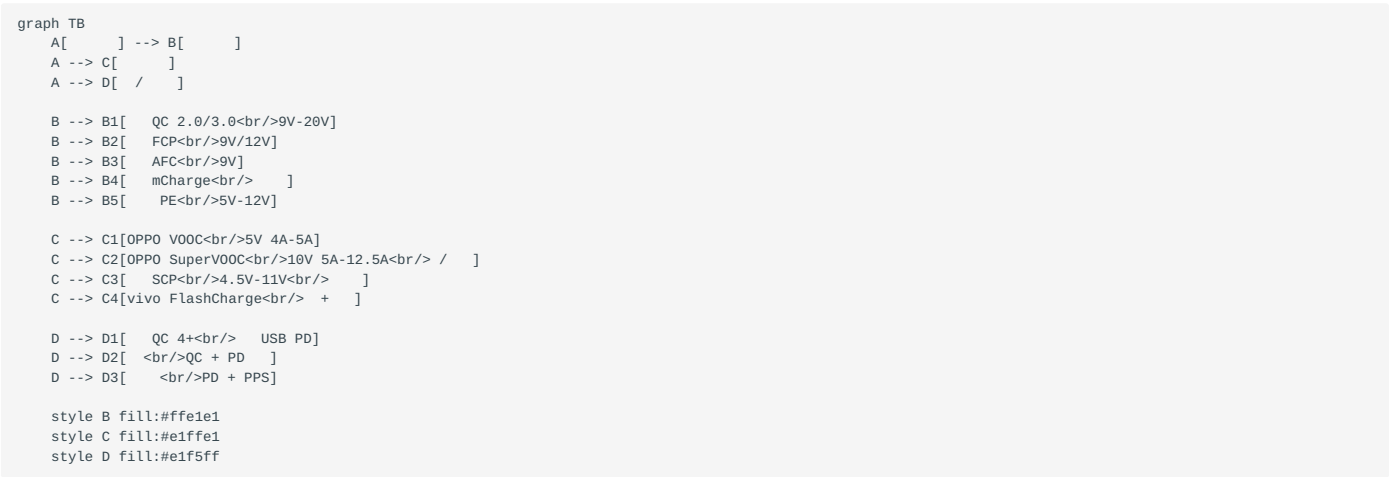
2019	:	OPPO SuperVOOC 2.0 (65W)	
	:	SCP 2.0 (40W)	
2020	:	QC 5 (100W+) :	PD
	:	(120W)	
2021	:	OPPO 125W/240W :	
	:	(210W)	
	:	vivo (200W)	
2023	:	Type-C :	

6.2.3

Handshake Protocol



1. 5V
2. D+/D-
3.
4. /
5.
- [!NOTE] D+/D- USB " "



6.2.4 Quick Charge (QC)

Quick Charge

Android

QC 1.0 (2013)

- 10W (5V 2A)

-
-

QC 2.0 (2014)

QC 2.0

- 18W
-
- Class A: 5V 9V 12V
- Class B: 5V 9V 12V 20V
- 3A
- D+/D-
- 5V D+ = D- = 0.6V
- 9V D+ = 3.3V, D- = 0.6V
- 12V D+ = 0.6V, D- = 0.6V
- 20V D+ = 3.3V, D- = 3.3V Class B

QC 3.0 (2016)

QC 3.0

- 18W 22W
- 3.6V - 20V
- 200mV QC 2.0
-
-
- 38% QC 2.0
-
- QC 2.0

QC 4 / QC 4+ (2017-2018)

QC 4/4+ USB PD

- 28W (QC 4) 100W (QC 4+)
-
- USB PD 3.0 PD
- PPS (Programmable Power Supply)
- INOV (Intelligent Negotiation for Optimum Voltage)
- QC USB PD
-

QC 5 (2020)

- 100W+
- 98%

•	USB PD	QC			
[!IMPORTANT] QC 4 USB PD QC 4+ PD iPhone MacBook					
<hr/>					

6.2.5 OPPO VOOC

OPPO	VOOC
------	------

VOOC (2014)

•	20W				
•	/	5V	4A		
•					
•		QC	5V	4A-5A	
•		7	Micro-USB	5	2
•					
•		MCU ()	
•					
•					
•					
•					

SuperVOOC (2018)

SuperVOOC			
•	50W		
•	/	10V	5A
•			
•		2000mAh	
•	10V		5V
•	5V	10V	5A
•			

SuperVOOC 2.0 (2019-2020)

- 65W
- / **10V 6.5A**
- OPPO Find X Reno

125W / 240W (2021-)

OPPO	- 125W	10V 12.5A	- 240W	24V 10A
[!WARNING] VOOC OPPO Type-C VOOC				

6.2.6 FCP / SCP

FCP (Fast Charge Protocol, 2015)

- 18W
- 9V / 12V
- 2A
- D+/D-
-

SCP (SuperCharge Protocol, 2016)

- SCPVOOC
- - SCP 1.0 22.5W (5V 4.5A 4.5V 5A)
 - SCP 2.0 40W (10V 4A)
 - SCP 3.0 66W (11V 6A)
 -
 -
 -
 -
 - FCP

[!NOTE] FCP SCP SCP FCP FCP FCP SCP

6.2.7 Pump Express (PE / PE+)

Pump Express Plus (PE+, 2015)

- 18-24W
- 5V - 12V
-
- D+/D-
-
-
- QC

Pump Express 3.0 (PE 3.0, 2017)

- 30W
- 3V - 6V
- USB Type-C Type-C
- 20 70%

USB PD PE

- 34 - 80%

		PD	QC
120W	120W	65W PD	18W QC 3.0
67W	67W	45W PD	18W QC 3.0
PD	27W-45W PD	PD	QC

[!TIP]

[!NOTE] 67W USB PD

6.2.10 (mCharge)

- 18W 24W 36W
- QC
-

6.2.11 AFC (Adaptive Fast Charging)

- 15W 18W
- 9V
- 1.67A (15W) 2A (18W)
- D+/D-
- QC 2.0 9V

[!TIP] USB PD + PPS AFC

6.3

QC 2.0/3.0	18W		
QC 4+	100W	USB PD	PD
VOOC/SuperVOOC	20-240W	OPPO/OnePlus/realme	
FCP	18W	/	
SCP	22.5-66W	/	
PE/PE+	18-24W	MTK	
AFC	15-18W	QC	

6.4

6.4.1

-
- 5V 1A/2A
-
- QC 2.0/3.0 9V
- QC + FCP

6.4.2

- VOOC
-
-

6.4.3 USB PD

[!IMPORTANT]		USB PD 3.0	PPS	Type-C	
-	QC 4+	USB PD -	PD -	PD + PPS - OPPO/	PD

6.4.4

- 1.
- 2.
3. USB PD USB PD
- 4.

6.5 USB PD (Power Delivery)

USB PD	USB-IF	Type-C
--------	--------	--------

6.5.1 USB PD

- ✗
 - ✗
 - ✗
 - ✗
- USB PD

6.5.2 USB PD

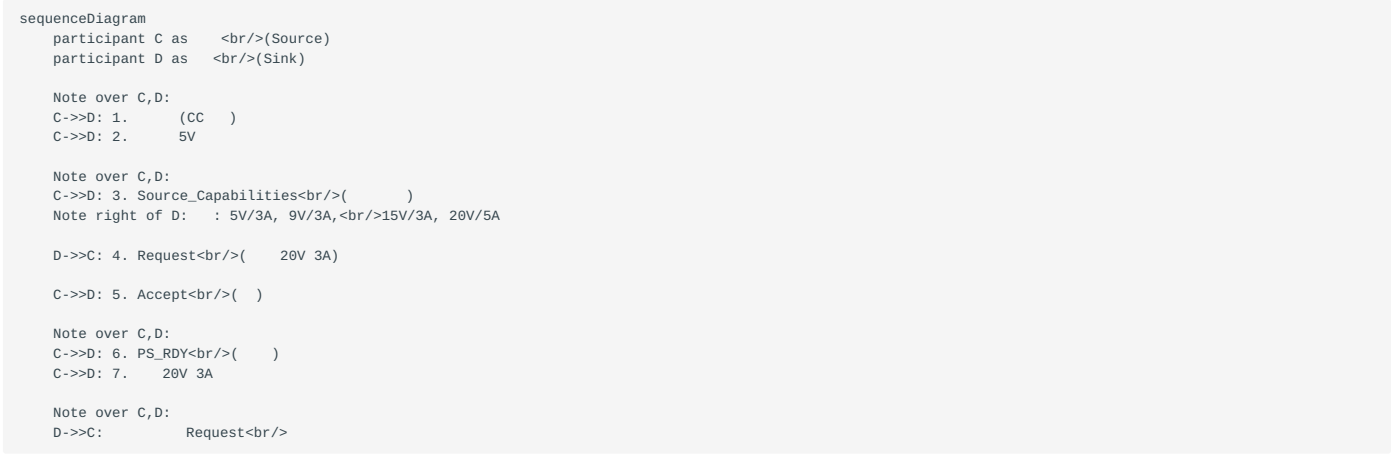
D+/D-	USB PD	CC	Configuration Channel
-------	--------	----	-----------------------

CC

1. Type-C
2. Source Sink
3. CC

4. PD

PD



1. Type-C CC
2. 5V
3. Source_Capabilities /
4. Request
5. Accept Reject
6. PS_RDY Power Supply Ready
7.

[!IMPORTANT] USB PD " " D+/D- " " PD

6.5.3 PD

USB PD		CC	
Source_Capabilities	Source → Sink		
Request	Sink → Source		
Accept	Source → Sink		
Reject	Source → Sink		
PS_RDY	Source → Sink		
Get_Sink_Cap	Source → Sink		
Soft_Reset	Both	PD	
Hard_Reset	Both	5V	

6.5.4

PD 2.0 / 3.0 (2016-2018)

- 100W (20V 5A)
-
- 5V
- 9V 12V 15V 20V
- 5A E-Marker
-
- - 45W 5V/3A, 9V/3A, 15V/3A, 20V/2.25A - 65W 5V/3A, 9V/3A, 15V/3A, 20V/3.25A - 100W 5V/3A, 9V/3A, 15V/3A, 20V/5A

PD 3.1 (2021)

- 240W (48V 5A)
- EPR (Extended Power Range)
- 28V 36V 48V
-
- EPR

6.5.5 PPS (Programmable Power Supply)

PPS USB PD 3.0

PPS

- PD 5V 9V 15V 20V - 9V 4.2V - 9V → 4.2V -

PPS

- 3.3V - 21V PD 3.0 PPS
- 20mV 0.02V
-

```
graph LR
    A[ PD<br/>9V ] -->| B[4.2V ] |
    C[PPS<br/>4.2V ] -->| D[4.2V ] |

    style A fill:#ffe1e1
    style B fill:#fff4e1
    style C fill:#e1ffe1
    style D fill:#e1ffe1

    Note1[ <br/> ]
    Note2[ <br/> ]
```

PPS

- ⚡
- 🔌
- 📶 5-10%
- 📱

PPS

PPS

PPS		
0-30%	3.6V	3.8V
30-70%	3.9V	4.1V
70-90%	4.1V	4.3V
90-100%	4.3V	4.4V

[!NOTE] " 2.0" "PD " PPS iPhone 15 Pro PPS

6.5.6 USB PD vs

USB PD		
✓	USB-IF	✗
✓		✗
CC		D+/D- /
		" "
	240W (PD 3.1)	240W (OPPO)
✓ PPS	20mV	QC 3.0 200mV
✓		
✓		✗
✓		⚠

- PD
1.

2024

USB-C
2.

PPS

PD
3.

PD
4.

[!IMPORTANT]OPPO

USB PD

" " " "

6.6(E-Marker)

- Type-C
- 3A

C-to-C

60W (20V 3A)
- 5A

E-Marker

" 5A "

100W (20V 5A)
- EPR

PD 3.1 240W

6.6.1 E-Marker

```
graph LR
  A[ ] -->|CC| B[ <br/>E-Marker ]
  B -->| | C[ ]

  B --> D[ :<br/>1. 5A<br/>2. <br/>3. <br/>4. ]

  style A fill:#ffe1e1
  style B fill:#e1f5ff
  style C fill:#e1ffe1
  style D fill:#fff4e1
```

[!WARNING]3A100W

60W

6.7

6.7.1 1

66W (SCP)	Mate 40 Pro	66W	65W	SCP	✓
66W (SCP)	11	66W	27W	USB PD	⚠ PD
66W (SCP)	iPhone 14 Pro	66W	27W	USB PD	⚠ PD iPhone
OPPO 65W (VOOC)	OPPO Find X5 Pro	65W	65W	SuperVOOC	✓
OPPO 65W (VOOC)	11	65W	10W		✗
OPPO 65W (VOOC)	iPhone 14 Pro	65W	0W		✗ VOOC PD
120W	12 Pro	120W	120W		✓
120W	iPhone 14 Pro	120W	27W	USB PD	✓ PD iPhone
120W	MacBook Pro 14	120W	96W	USB PD	✓ PD
140W (PD)	MacBook Pro 16	140W	140W	USB PD 3.1	✓
140W (PD)	12 Pro	140W	67W	USB PD	✓ PD
140W (PD)	Mate 40 Pro	140W	27W	USB PD	✓ PD SCP

✓ USB PD ✓ - ⚠ + PD - SCP ✗ PD - OPPO VOOC

6.7.2 2

11 Pro (67W) + 67W

0-50%			
6A	67W	15	✓
5A E-Marker	60W	17	⚠
3A	18W	45	✗
	10W	70	✗
1	67W	15	✓
3	25W	35	⚠

- - - - >60W 5A/6A

6.7.3 3

1	PD	-	Anker	-	100W / 140W USB-C PD	-	USB PD 3.0/3.1 + PPS + QC 4+ -
	Switch	-					
2	GaN	-	Anker	-	100W / 120W	2C1A / 3C1A	- USB PD 3.0 + PPS + QC 3.0/4+ -
		-	Anker 747 (150W)	-	100W (C1) / 100W (C2)	- 100W + 50W	- 65W + 45W + 40W
3		-	Baseus Ugreen	-	200W+	4-6	-
[!TIP]	GaN				100W GaN		1/3

6.8

6.8.1

USB BC 1.2	USB PD
(OVP)	5-10V +
(OCP)	MCU CC
(OTP)	/
(SCP)	
	BMS + BMS + PD
	E-Marker
	PS_RDY
	Role Swap

6.8.2

1.
2. USB-IF
3. USB-IF
4. " "
5.
6. /
7. >50°C
8. VOOC/SuperVOOC
9.
10. 100%
11. 80-90% " "
12.
13. <0°C >40°C
14.
15.

16.
17.

6.9

USB-IF	USB Implementers Forum	USB	USB	
D+/D-	Data Plus / Data Minus	USB		
CC	Configuration Channel	Type-C	PD	
E-Marker	Electronically Marked Cable			
MCU	Microcontroller Unit			
BMS	Battery Management System			
	Direct Charging			
	Dual-Cell Battery			
	Multi-Tab			
	Handshake Protocol			
GaN	Gallium Nitride			
PPS	Programmable Power Supply	PD 3.0	20mV	
EPR	Extended Power Range	PD 3.1	28V-48V	240W
OVP	Over Voltage Protection			
OCP	Over Current Protection			
OTP	Over Temperature Protection			
SCP	Short Circuit Protection	SuperCharge Protocol		
C-to-C	USB-C to USB-C	Type-C	Type-C	
A-to-C	USB-A to USB-C	USB-A	Type-C	

6.10

6.10.1

- [USB Power Delivery Specification \(USB-IF \)](#)
- [USB Type-C® Cable and Connector Specification](#)
- [Qualcomm Quick Charge](#)

6.10.2

- **POWER-Z** USB
- **ChargerLAB KT002** PD
-

6.10.3

- USB-IF

[!NOTE]	2023	USB-IF
---------	------	--------

7. 6

(FAQ & Common Misconceptions)

7.1 Q:

Type-C

A:

1.

VOOC

10W

USB 2.0

3.

E-Marker

3A

65W/100W

2.

PD

7.2 Q:

Type-C

A:

Type-C

C

-9.9

+ USB 2.0

-

USB 3.2 (10Gbps) + 4K

+ 100W

-

4

40Gbps

+ 8K

+ 240W

Logo

7.3 Q:

65W

A:

USB PD

"

"

"

9V 2A "

18W

PD

5V 1A

5V 2A

7.4 Q:

A:

-

5A

4

-

USB 3.2